MATERIALS BUREAU

MATERIALS MANUAL

FIELD SURVEY MANUAL FOR BRIDGE DECK OVERLAY PROJECTS

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NEW YORK STATE DEPARTMENT OF TRANSPORTATION

FIELD SURVEY MANUAL FOR BRIDGE DECK
OVERLAY PROJECTS

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PREFACE

Many monolithic concrete slabs exhibit surface distress such as delamination and spalling. Some factors which contribute to these conditions are deficient concrete cover over top reinforcing steel, infiltration of deicing chemicals, and sometimes poor quality concrete. The result of a combination of these factors is corrosion of the top reinforcing steel. The build up of corrosion products causes severe tensile stresses in the concrete which leads to delamination and spalling. However, the spalls that are visually evident represent only the "tip of the iceberg". Many areas that appear to be in good condition possess some of the factors noted above and, if left untreated, represent future sites of concrete deterioration. Therefore, any slab evaluation must include procedures to detect these conditions. Procedures and techniques described in this manual will provide input to the design process so that an accurate estimate of concrete removal work can be computed and shown on the contract plans.

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INTRODUCTION

Methods for concrete bridge deck evaluation have been developed that, when combined with traditional methods, provide a more comprehensive description of the deck condition. This information can be used to more accurately determine the type and extent of repairs.

Evaluation methods and a brief description of their purpose are:

Evaluation Method	Purpose
Reinforcing Steel Corrosion Potential (Valid only on uncoated steel reinforcing bars.)	Determines areas of actively corroding reinforcing steel. Corrosion causes delaminations and spalls in the concrete deck. Determines extent of concrete removal required.
Depth of Concrete Cover over Reinforcing Steel	Determines depth of concrete cover. Inadequate cover contributes to early chloride penetration. Determines final grade of repair.
Chloride Analysis	Determines depth of chloride penetration and quantities of chloride ion present in concrete. Chloride ion concentration higher than 1 to 1.3 lb./cu.yd. induces reinforcing steel corrosion if moisture and oxygen are present.
Delamination Detection - Chain Drag or Hammer	Determines delaminated areas not visually evident.
Visual Inspection	Locates cracks, spalls, patches and other obvious signs of distress.
Data Verification Calibration Cores	Investigates areas where structural integrity of deck is suspect or where depth of deterioration is unknown. Used in any questionable areas not adequately defined by other techniques. Also used to verify accuracy of cover meter and potential data.

I EMPLOYEE SAFETY AND TRAFFIC MAINTENANCE

Bridge deck surveys are usually performed on structures which are in service. In rare instances it is possible to shut down the entire structure while the survey is being performed, but in most cases traffic must be maintained during the survey. It is imperative that the survey crew provide for safe traffic operation on the structure during the survey, and that they take all necessary safety precautions to protect themselves from injury.

Traffic protection should be provided in accordance with Appendix 7 of the State of New York Manual of Uniform Traffic Control Devices (MUTCD) Figures MC-5A, 7A, 10, 11, or 12 for stationary work of short duration. A copy of that portion of the MUTCD is included in the Appendix of the Highway Maintenance Subdivision's Safety Manual. Specifically, signs, vehicles, cones, flagmen, etc. should be placed in conformance to the MUTCD. However, these are minimum requirements; each situation may require judgement as to what constitutes proper traffic control. For example, if for a given work site more equipment is needed to safely control traffic (such as reduced speed signs, cones, trucks, etc.), be certain to arrange for the necessary equipment.

ALWAYS REFER TO THE MOST CURRENT SAFETY STANDARDS.

Before coring a deck, review the plans for electrical or other duct work cast into the concrete deck. Have a utility company mark locations, if necessary, and keep personnel from coring or using other excavating equipment in those areas.

II GRID LAYOUT

The deck condition survey must be performed in such a manner that people not involved in the survey can relate the data to the structure. For this reason several conventions of the Bridge Inventory and Inspection System have been adopted so that a uniform set of field procedures are followed by each survey crew. The following instructions explain how the survey crew will lay out a coordinate system on the bridge to which <u>all</u> data will be referenced.

Prior to going out in the field, the survey crew should prepare an accurate (1"=10') drawing of each slab-span based on the record plans for the structure. The drawing should include the following information:

1. Bridge Identification Number
2. Slab-span number
3. Skew angle of transverse joint at each end (skew angle shown on plans may not be the skew angle of the transverse joints)
4. Centerline radius
5. Length of slab-span along each curb
6. Width of slab-span (perpendicular to the centerline)
7. Station locations of beginning and ending joints
8. Direction of survey
9. North arrow

The drawing is used to determine a suitable grid layout for the slab-span. A copy of the drawing is used to record the location of cracks, delaminations, spalls, and patches.

Examples of suitable drawings for a tangent and curved slab-span are shown in Figure 2-1. A copy of this drawing should be used to determine an appropriate grid layout before going out in the field. This is useful to make certain the survey is performed in the right direction and the grid is laid out properly. In the drawings shown, the upper left hand corner is used as the reference point for each data grid.

The first choice facing the survey crew is to determine on which end of the structure to begin. The survey will always be started at the end with the lower stationing according to the record plans, and proceed in the direction of increasing stations (see Figure 2-2). Once the beginning end of the structure has been determined, the survey crew can begin to lay out a grid on each slab-span of the deck. A slab-span is defined as that portion of the bridge deck contained between two successive transverse joints. Approach slabs are surveyed in the direction of increasing stationing as well.

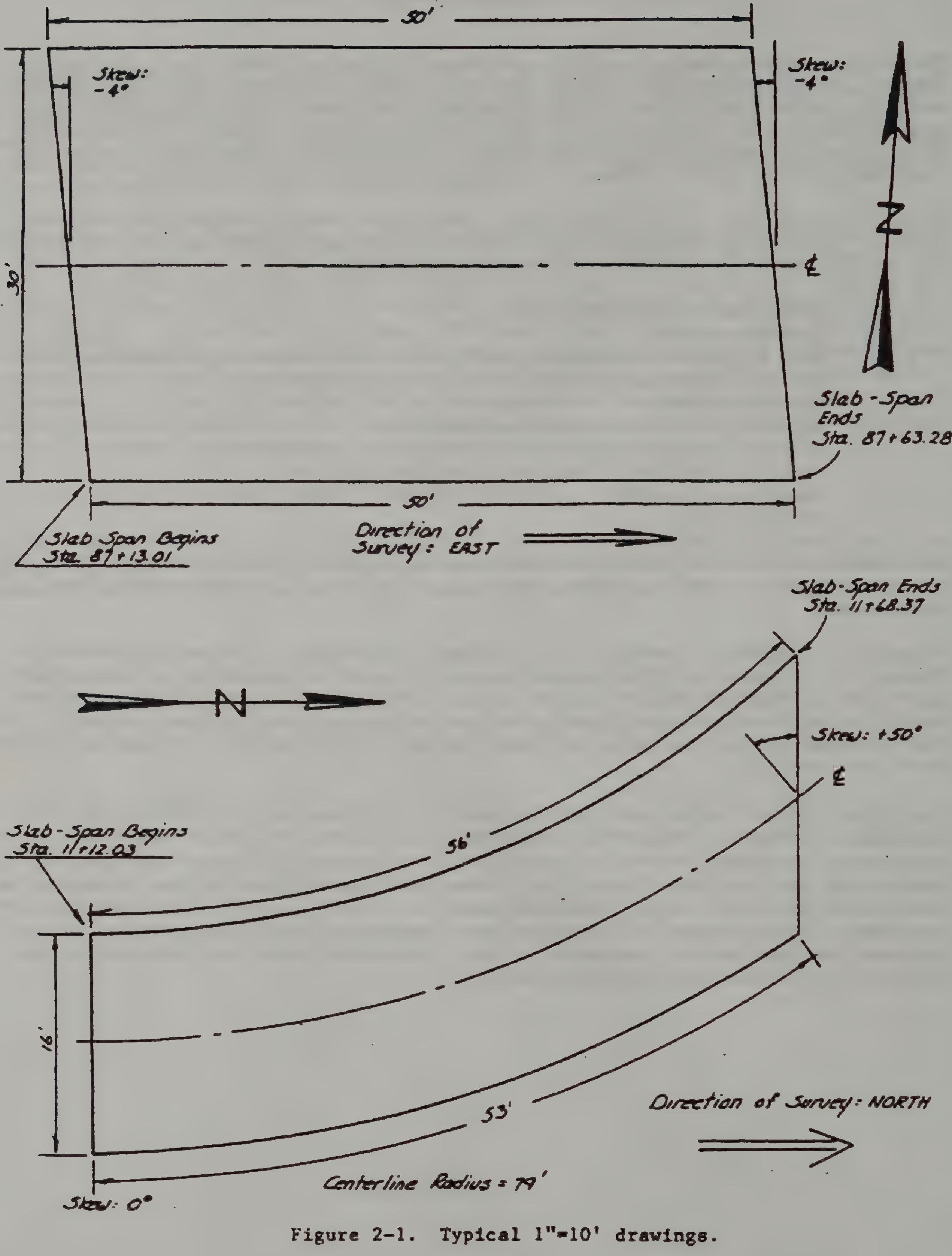

Figure 2-1. Typical 1"=10' drawings.

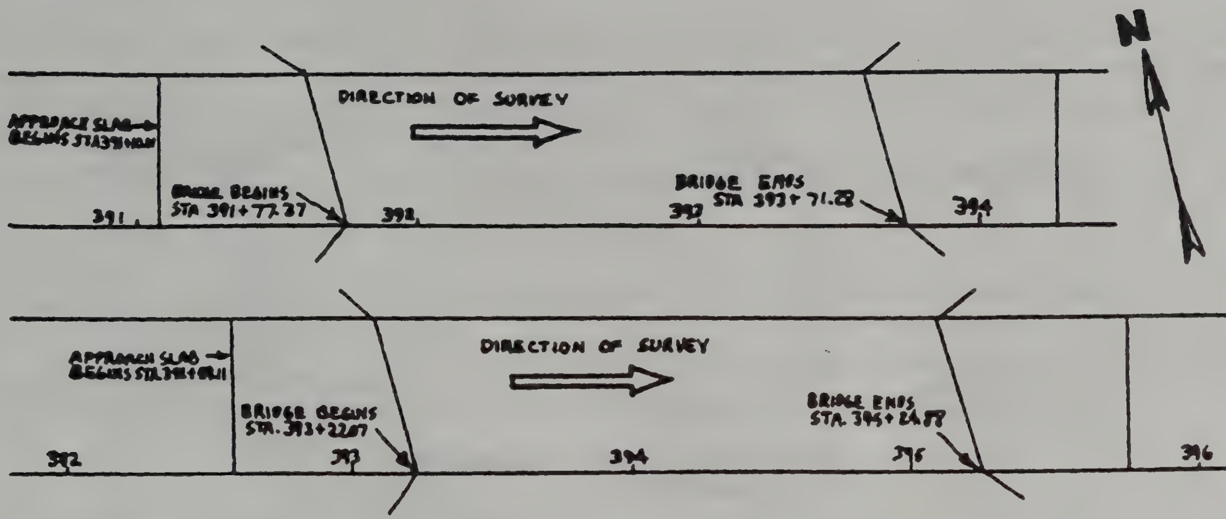

Figure 2-2. Direction of survey.

All decks will be surveyed using a two dimensional grid. However, there are some differences in the methods used to lay out a grid on a tangent (straight) structure and on a curved structure. For the purposes of the bridge deck condition survey, a slab-span with a centerline radius less than or equal to 1910 feet (a degree of curvature greater than or equal to 3 degrees) is considered a curved slab-span. Slab-spans with a centerline radius greater than 1910 feet are considered to be tangent slab-spans and a rectangular grid should be used as outlined in the following instructions. Procedures for laying out a grid on a curved slab-span are given in Section B of this chapter. Approach slabs are surveyed using the same procedures given for slab-spans.

A. <u>Tangent Slab-spans: Radius Greater Than 1910 Feet</u>

Each measurement made on the slab-span at a particular position has a transverse and longitudinal location associated with it. In order to identify those locations for future reference, it is necessary to define a particular reference point on each slab-span from which the longitudinal and transverse locations are measured. The reference point for all measurements shall be the left corner of the slab-span or approach slab at the transverse joint with the lower stationing according to record plans when looking in the direction of survey. (See Figure 2-3).

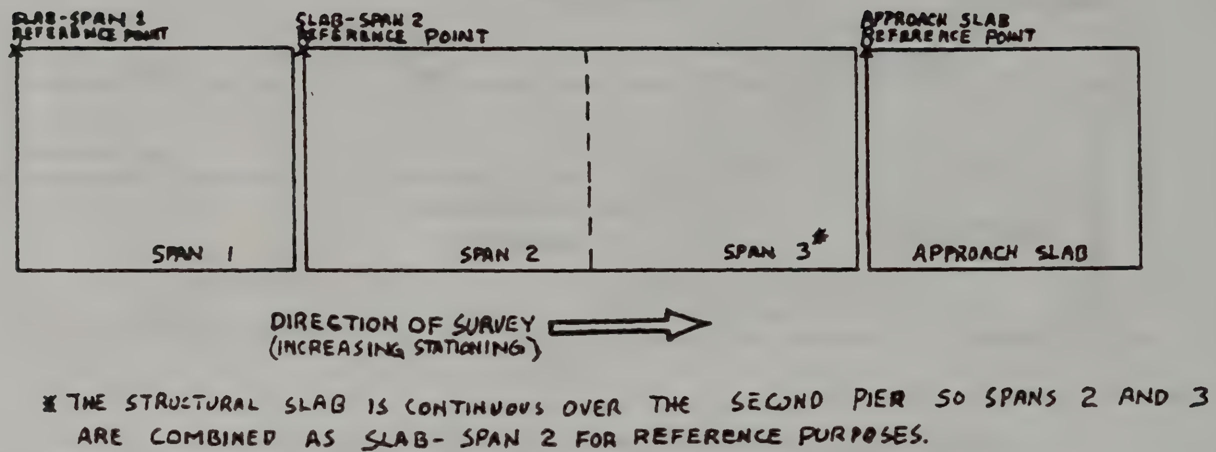

Figure 2-3. Determination of reference point.

The transverse location is defined as the distance, to the nearest foot, measured perpendicular to the pavement centerline from the face of the left curb, or if none, the edge of the fascia on the left side, to the point in question (see Figure 2-4).

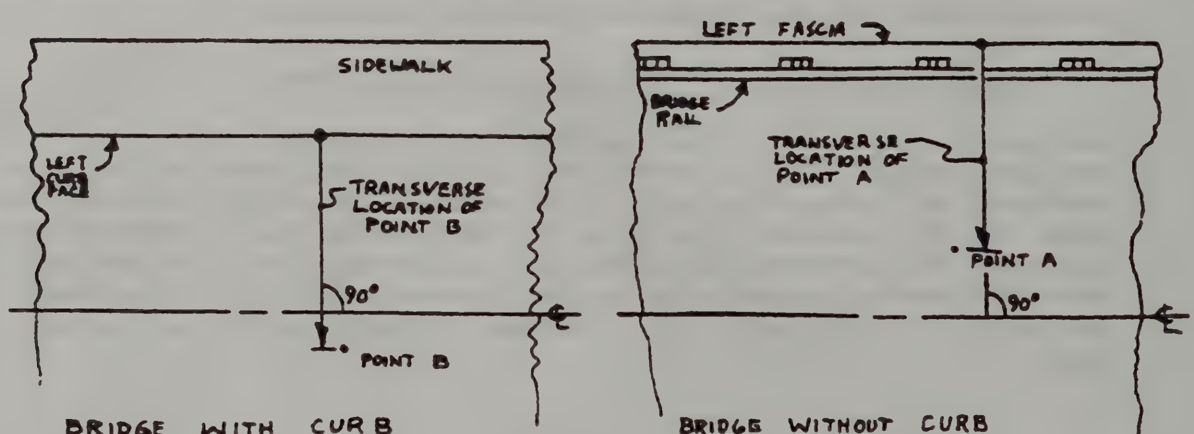

Figure 2-4. Determination of transverse location.

Grid Layout

The longitudinal location is defined as the distance, to the nearest foot, measured along the curb from the edge of the transverse joint with the lower stationing, to the point in question (see Figure 2-5). On curved structures this is measured along the curb as an arc, not a chord.

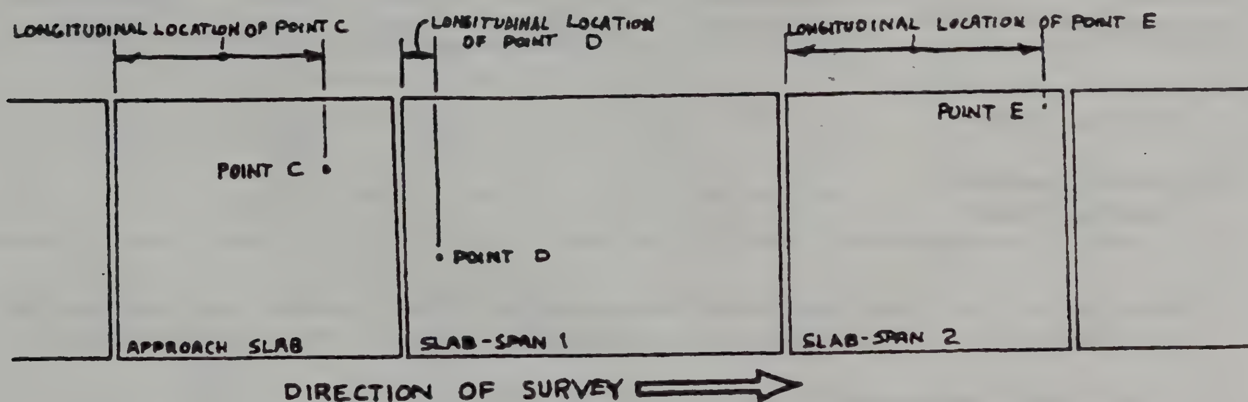

Figure 2-5. Determination of longitudinal location.

The survey crew should begin laying out the grid by marking the appropriate intervals along the left curb or left fascia from the edge of the transverse joint. A cloth tape is sufficiently accurate to determine these locations on the deck. Table 2-1 gives grid interval sizes for the most common measurements made during a bridge deck condition survey. Since the five foot by five foot grid is common to all measurements, this should be laid out first. Additional points may then be located as needed relative to the existing grid. Smaller intervals may be used if there is reason to believe more accurate data is required, but the suggested intervals in the table are the minimum necessary for analysis of the deck condition. The intervals may be conveniently marked with a spot of paint.

After the longitudinal intervals have been laid out along the left side of the deck, the crew should lay out a transverse line at each longitudinal interval by approximating a line perpendicular to the deck centerline. The line should be marked with paint or crayon at the appropriate intervals. An example of a tangent deck with three slab-spans, each with its own five foot data grid, is shown in Figure 2-6. Longitudinal locations were determined relative to the edge of the transverse joint with the lower stationing at intervals of five feet. Transverse locations were determined relative to the left curb at five foot intervals, but the first transverse location used was two feet. This may be adjusted as desired to accommodate the slab-span being surveyed, e.g. the first transverse location may be one foot to include readings adjacent to the curb or four feet to include the wheelpath. In addition, readings do not have to be made at fixed intervals if there is some reason to vary from the grid. However, it is easier to lay out the grid using fixed intervals and this convention should be followed in most cases.

TABLE 2-1

GRID INTERVALS

Type of Measurement	Corrosion Potential	Chloride	Depth of Cover	Calib. Core	Delaminations, Spalls, and Patches
Suggested longitudinal interval (feet)	5[a]	*	10	*	*
Suggested transverse interval (feet)	5[a] [b]	*	5[b]	*	*

* There is no fixed rate for these measurements. Their number and location are to be determined in accordance with Chapters IV, V, and VII of this manual.

(a) Additional measurements may be made at visible cracks.

(b) Due to variations in the deck and its environment, it is desirable to locate the first transverse point two feet from the left curb or three feet from the left fascia. On the right side of the deck, an additional transverse location should be added approximately two feet from the curb if the last transverse location is four feet or more from the curb.

In the example shown in Figure 2-6, the slab-spans are skewed such that the first point on the deck is the left corner which was assigned a longitudinal location zero. In many instances the slab-span will be skewed in the opposite direction as shown in Figure 2-7. When this occurs, the survey crew must lay out a transverse line perpendicular to the centerline passing through the right corner of the slab-span at the beginning transverse joint. This line is assigned a longitudinal location zero where it intersects the imaginary extension of the left curb or fascia. The remaining longitudinal locations will all be determined relative to this point.

B. Curved Slab-spans: Radius Equal To Or Less Than 1910 Feet

The grid system used for slab-spans with horizontal curves is similar to that used for tangent slab-spans; longitudinal locations are measured as an arc along the left curb and transverse locations are measured along radial lines from the left curb or fascia. Although the method used is relatively simple, the existence of skewed joints and highly curved slab-spans can make it difficult to lay out the grid by eye. The survey crew should determine the actual layout based on record plans for the structure.

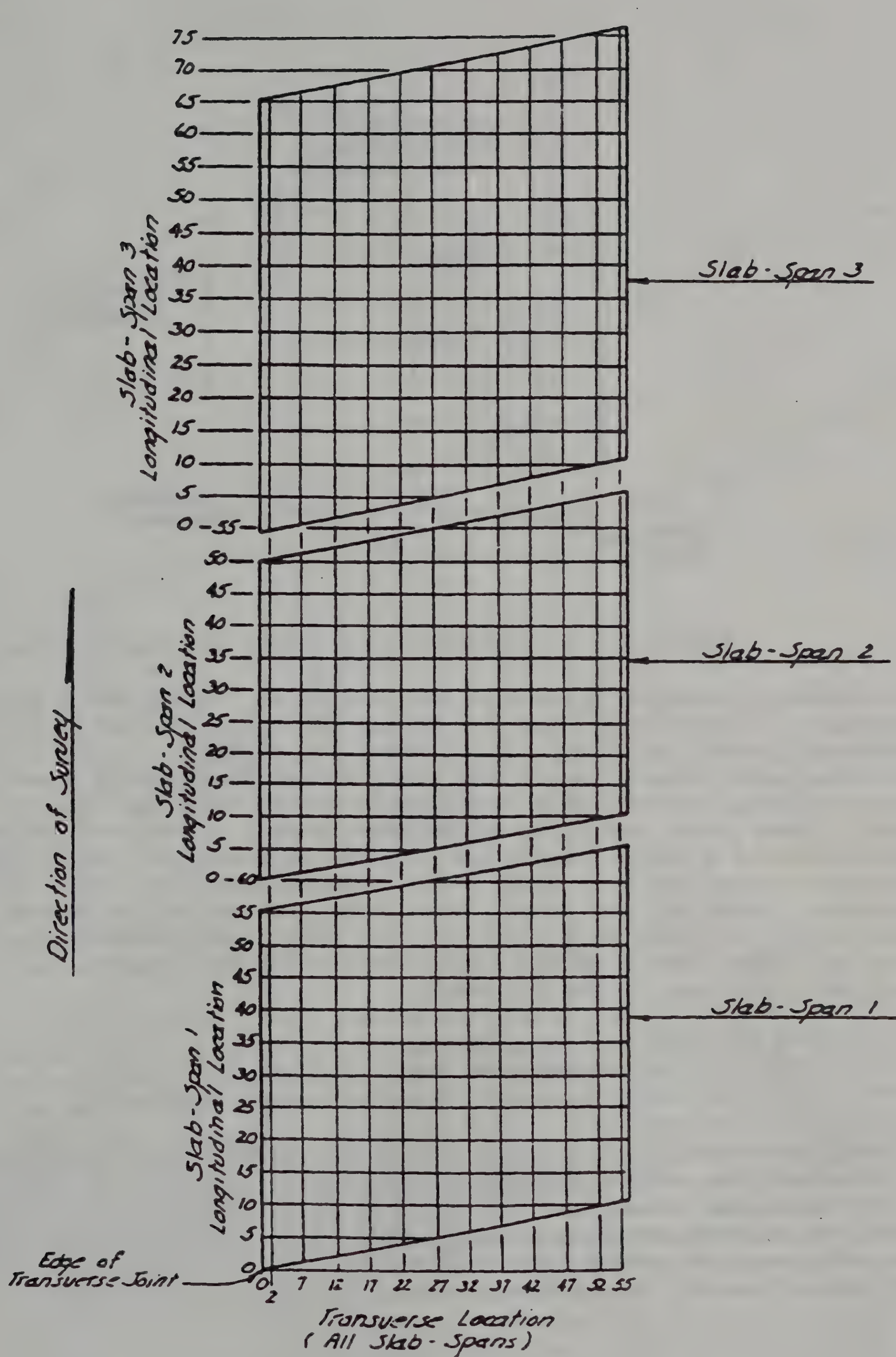

Figure 2-6. Tangent deck with five foot grid.

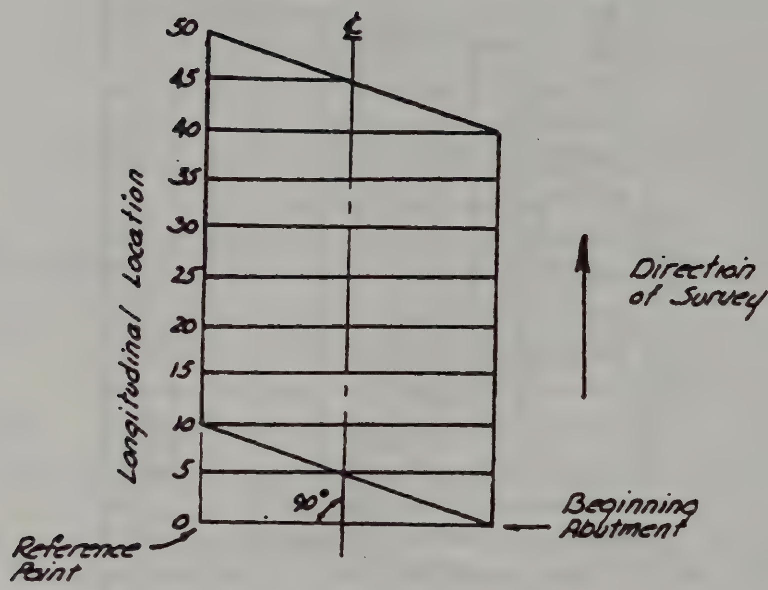

Figure 2-7. Longitudinal locations on tangent deck.

The following examples illustrate the method for laying out a grid on curved slab-spans. Figure 2-8A shows a slab-span with zero skew at both ends, i.e. the transverse joints lie along radial lines perpendicular to the curb. In this case, the survey crew lays out the longitudinal locations by measuring five foot intervals along the left curb or fascia, starting from the edge of the transverse joint. These points should be marked with a spot of paint or crayon. Next, the intersection of a radial line drawn from the farthest longitudinal location to the right curb should be determined. The distance along the right curb, from the transverse joint to that point, should be divided by the number of whole longitudinal grid intervals along the left curb. This interval should be laid out along the right curb as shown. An alternate way to determine the interval used along the right curb is the following:

$S_2 = S_1 \frac{R_2}{R_1}$ where R_1 = radius of the left curb,
R_2 = radius of the right curb,
S_1 = interval along left curb (usually 5')

The line connecting each successive pair of points along the right and left curbs is a radial line used to determine transverse locations. On some structures it may be impossible to work on both curbs at the same time due to traffic. In those cases, the formula shown above may be used to determine the appropriate spacing on any reference line with a known radius, such as the centerline. In this manner, the radial lines may be laid out a lane at a time if necessary.

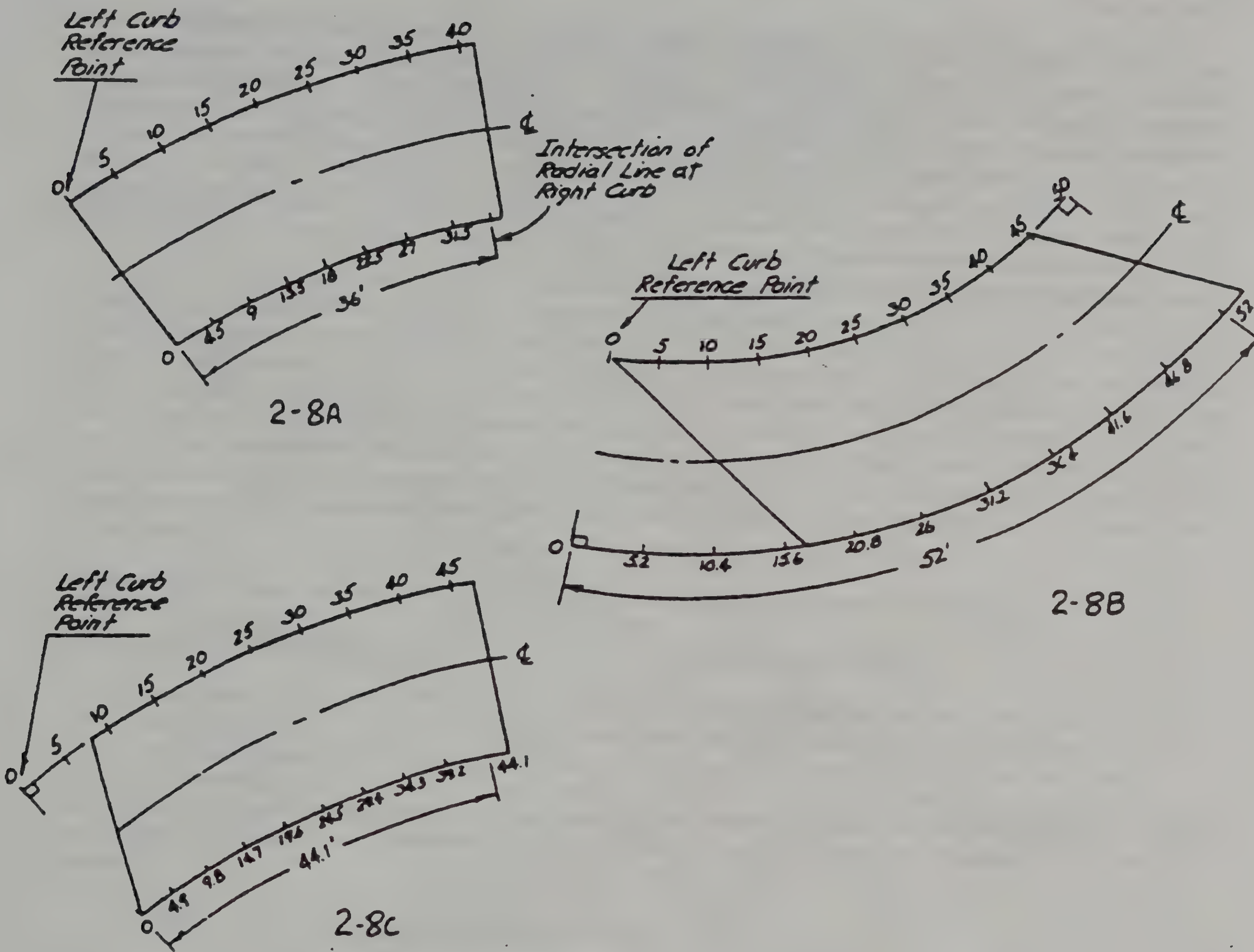

Figure 2-8. Longitudinal locations on curved decks.

Figures 2-8B and C show curved slab-spans with skewed transverse joints. In these cases, radial lines constructed on the slab-span from the left curb will not cover the entire slab-span. In Figure 2-8B, the transverse joint at the beginning abutment is skewed such that the radial line passing through the transverse joint at the left curb intersects the right curb approximately 17 feet from the transverse joint. At the far end of the slab-span, the joint is skewed such that a radial line constructed at the 45 foot longitudinal location on the left curb does not provide grid points in the last 10 feet of the slab-span on the right. For this reason, an additional longitudinal location must be determined along the imaginary extension of the left curb or fascia at the 50 foot point. A radial line constructed from that point intersects the right curb or fascia approximately 52 feet, measured along the right curb, from the intersection of the radial line passing through the zero longitudinal location. Since there are ten intervals laid out along the left curb, the 52 feet is divided by 10 to yield 5.2 feet intervals for the right curb. When laid out as shown, these intervals locate the end points of the radial lines to be used for the grid.

In Figure 2-8C a similar problem is encountered at the beginning transverse joint. In this case, the zero longitudinal location is the point where a radial line passing through the first point encountered on the slab-span (the right corner) intersects the imaginary extension of the left curb or fascia. All other longitudinal locations are then measured relative to this point.

The transverse locations are measured from the left curb or fascia along radial lines laid out perpendicular to the left curb. Figure 2-9 shows a skewed, curved slab-span with a five foot grid.

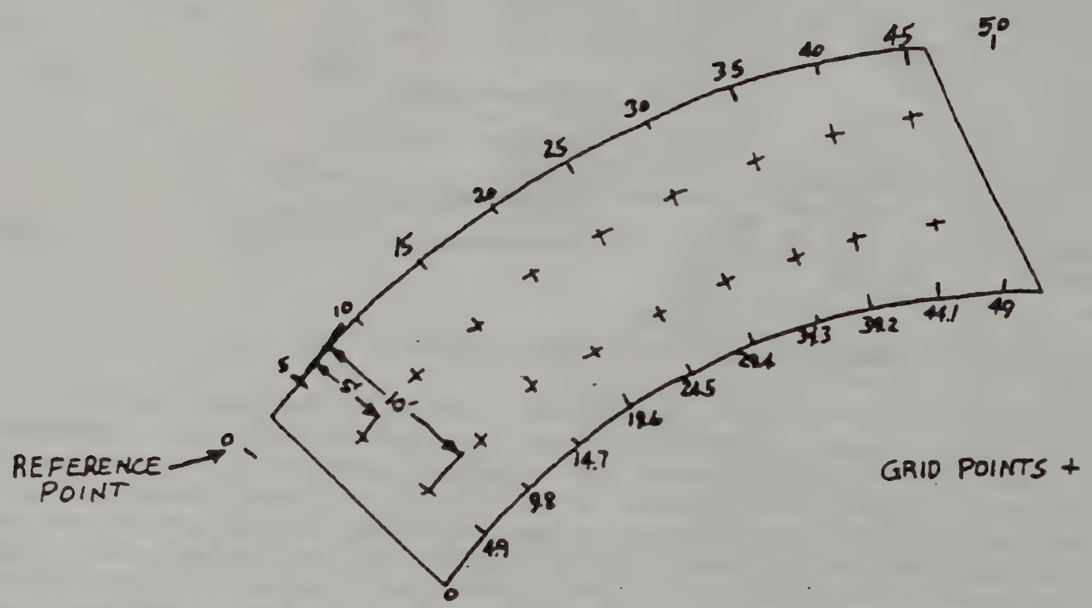

Figure 2-9. Curved deck with five foot grid.

C. <u>Complex Slab-spans</u>

In some instances, a survey crew may encounter a complex slab-span with both tangent and curved portions, such as ramp entrances. In order to lay out a grid on this type of slab-span, it must be divided into tangent and curved portions, each with its own grid.

III REINFORCING STEEL CORROSION POTENTIALS

Delamination and spalling of portland cement concrete bridge decks are caused primarily by expansive forces due to corrosion of the reinforcing steel. Chloride ions from deicing salts accelerate corrosion by activating the surface of steel reinforcement and increasing the electrical conductivity of the concrete deck. Since the corrosion products are more voluminous than the steel itself, large tensile stresses develop in concrete at the level of the top reinforcing bars, which results in cracks and delamination. Delaminated areas usually result in "potholes".

Actively corroding and passive areas of reinforcing steel may be located by conducting a corrosion potential survey of the deck on a five by five foot grid using a copper-copper sulfate half-cell. The half-cell has a constant voltage which, when connected to the reinforcing steel, provides a reference for measuring the corrosion potential of the steel. The circuit begins with a ground wire which is attached directly to the reinforcing steel from the negative (common) terminal of a high impedance voltmeter. A second wire connects the positive terminal of the voltmeter to the copper-copper sulfate half-cell. The circuit is completed by moisture in the concrete deck when the porous end of the half-cell is placed on the deck.

Corrosion potential values indicate the following corrosion activity.

Potential Values (volts)	Corrosion Activity
Less than 0.20	Greater than 90% chance of no corrosion
0.20 to 0.35	Corrosion may or may not be occurring
Greater than 0.35	Greater than 90% chance of active corrosion

A more detailed explanation of the corrosion reaction and use of the copper-copper sulfate half-cell to measure corrosion potentials is in the Appendix of this manual.

A. Ground Connection to Reinforcing Steel

A LOW RESISTANCE ELECTRICAL CIRCUIT MUST BE ESTABLISHED. A poor ground or loose connection increases resistance in the circuit which raises the measured potential values by an unknown amount. This problem is compounded by the fact that induced error is not easily recognized.

The ground is obtained by making a direct connection to a reinforcing bar in the slab-span where readings are to be taken. Although it is possible to establish a low resistance circuit by grounding to a bridge rail or some other metal appendage that is connected to the reinforcing steel, such a circuit may be influenced by potentials generated by dissimilar metals or different grades of steel. These grounds are <u>not</u> to be used, as they can induce large errors into the corrosion potential readings.

Reinforcing Steel Corrosion Potentials

If reinforcing bars are not exposed or accessible for making a ground connection, locate a transverse bar with the cover meter in any easily accessible area such as an asphalt patch or where the concrete cover is shallow. If possible, the ground should be located adjacent to the cones separating traffic from the work area. In this way, the same connection may be used when traffic is shifted to the other lane. Use a long enough ground wire (approximately 12 ft.) so that you can be in a safe position. A cold chisel and hammer will easily expose the bar under an asphalt patch. Other methods, such as a core drill or jackhammer, will be necessary to expose a reinforcing bar in sound concrete. Once exposed, incline the cold chisel at about 45 degrees and chisel until a portion of the bar has been curled up as shown in Figure 3-1. An alligator or spring clamp can be used to make the connection. If the entire bar is easily exposed, the clamp can be placed on the sides of the bar, but only after cleaning to bright metal.

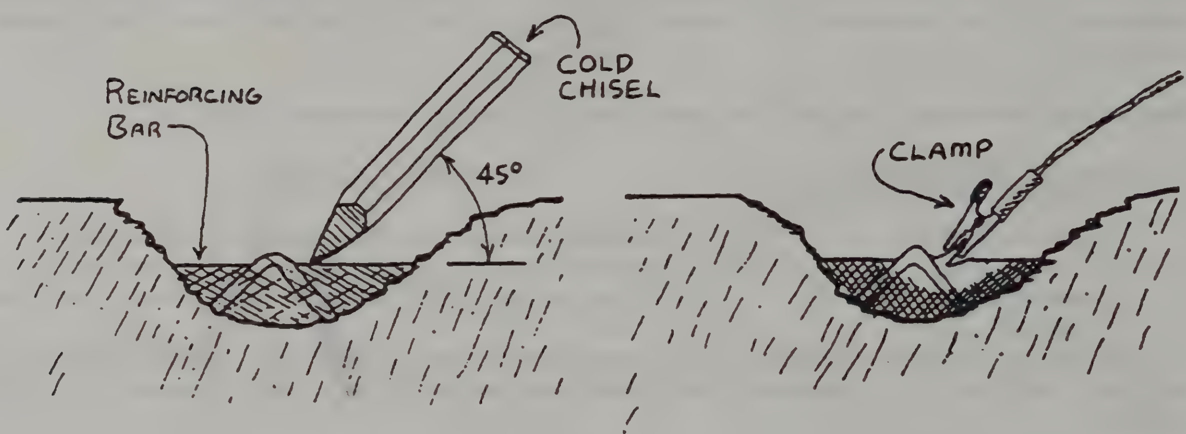

Figure 3-1. Reinforcing bar ground connection.

A circuit check for resistance must be made between the reinforcing bar ground connection and either a scupper, armored bridge joint, bridge rail bolt or another reinforcing bar. A good ground and low resistance circuit will have a resistance of less than 5 ohms and consistent values, within two ohms, on two ranges of the meter. The leads should be reversed at the meter to check the resistance on both polarities; these values should also be within two ohms of each other.

When a circuit check is being done, connections to scuppers, armored bridge joints or bridge rails should be made with a C-clamp or sturdy clamp type connector. Rust, dirt, and non-conductive coatings should be removed by using emery cloth or a file so that bright metal is exposed.

B. Establishing A Low Resistance Circuit

1. Zero meter (if applicable) and check battery. Set meter aside while it reaches ambient temperature.

2. Find two possible ground connections (one must be a reinforcing bar) for resistance check.

3. Curl up top of reinforcing bar(s) with a hammer and chisel.

4. Clean ground connection to bright metal with emery cloth or file. The curled up reinforcing bar(s) may be clean enough.

5. Set the meter function switch to read ohms and set the range at 0-100 ohms or some equivalent scale so that meter resolution is 1 ohm or less. Zero meter.

6. Attach primary ground lead to negative (common) terminal of meter.

7. Attach secondary ground lead to positive terminal of meter. Connect a short lead (with an attached clamp) to the other end.

8. Connect primary and secondary ground clamps together and read meter. Resistance should be well below 1 ohm (approximately 0.1 ohm).

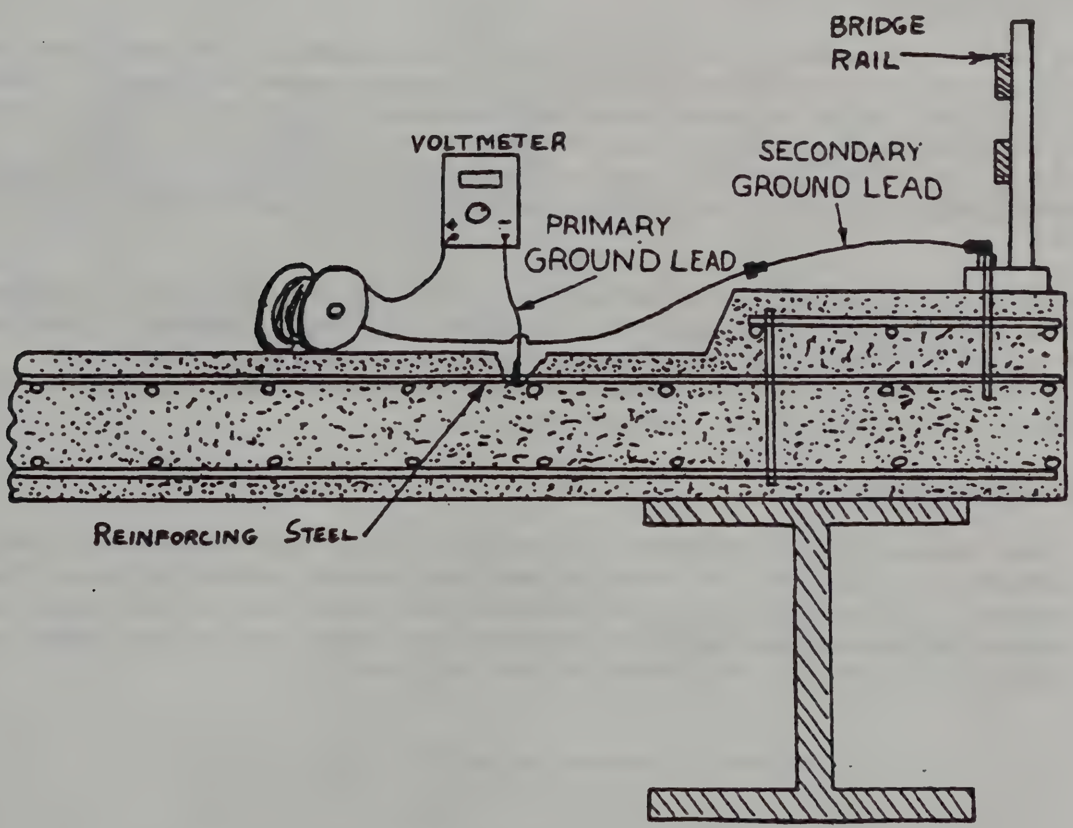

Figure 3-2. Checking circuit resistance and ground.

9. Attach primary ground clamp to rebar. Attach secondary ground clamp to secondary ground connection. Read meter. Resistance must be under 5 ohms. Reverse polarity (switch positive and negative connections on meter) and reread. Resistance must be under 5 ohms and within 2 ohms of first reading. (See Figure 3-2 for schematic of hookup.)

10. If resistance is greater than 5 ohms, there is an improper ground or bad connection somewhere in the circuit. Disconnect secondary ground clamp and attach it next to the primary ground clamp on rebar. If resistance drops below 3 ohms, secondary ground may be unacceptable. If resistance does not drop below 3 ohms, recheck primary ground connection and all wire and meter connections.

    If infinite resistance was obtained or resistance changed appreciably, the secondary ground is probably not adequately connected to the grid of reinforcing steel in the deck. Change location of the secondary ground to another rail bolt, armored joint system, scupper, or another rebar and retest circuit.

    If still not able to obtain a low resistance circuit, there may be a primary ground connection to an isolated rebar. Select another rebar and repeat.

C. Pre-wetting Grid Points

Pre-wet each grid point on the deck with a small quantity of electrical contact solution, which is tap water containing a wetting agent or liquid household detergent. The ratio of liquid detergent to water is 1:200 by volume (3.2 ounces (95 milliliters) of detergent per 5 gallons (19 liters) of water). At temperatures below 50°F (10°C), approximately 15% by volume of either isopropyl or denatured alcohol should be added to the solution to improve penetration into the concrete.

Pre-wet 5-10 minutes prior to using the half-cell to allow the solution to penetrate the concrete surface. If the solution should evaporate from any grid points prior to obtaining a reading, solution should be applied again. Do not over apply solution such that standing water is present when readings are taken or grid points are connected by surface water.

D. Half-cell Hookup

1. Check copper-copper sulfate half-cells to see that they are filled with saturated copper sulfate solution and that excess copper sulfate crystals are present. If more solution is required, add distilled or deionized water and reagent grade copper sulfate crystals so there are always some excess crystals present in the bottom of the half-cell.

2. Remove plastic cap from porous end of half-cell and place a sponge saturated with electrical contact solution over the end.

3. Allow half-cells to come to equilibrium with ambient temperature.

4. Set meter function switch to read DC volts and set range to read 1/1000 of a volt (0.000 volts).

5. Zero meter as per instructions with meter, if necessary.

6. Exchange the secondary ground short lead (with attached clamp) with the half-cell lead. Attach half cell lead to half cell. (See Figure 3-3 for schematic of equipment.)

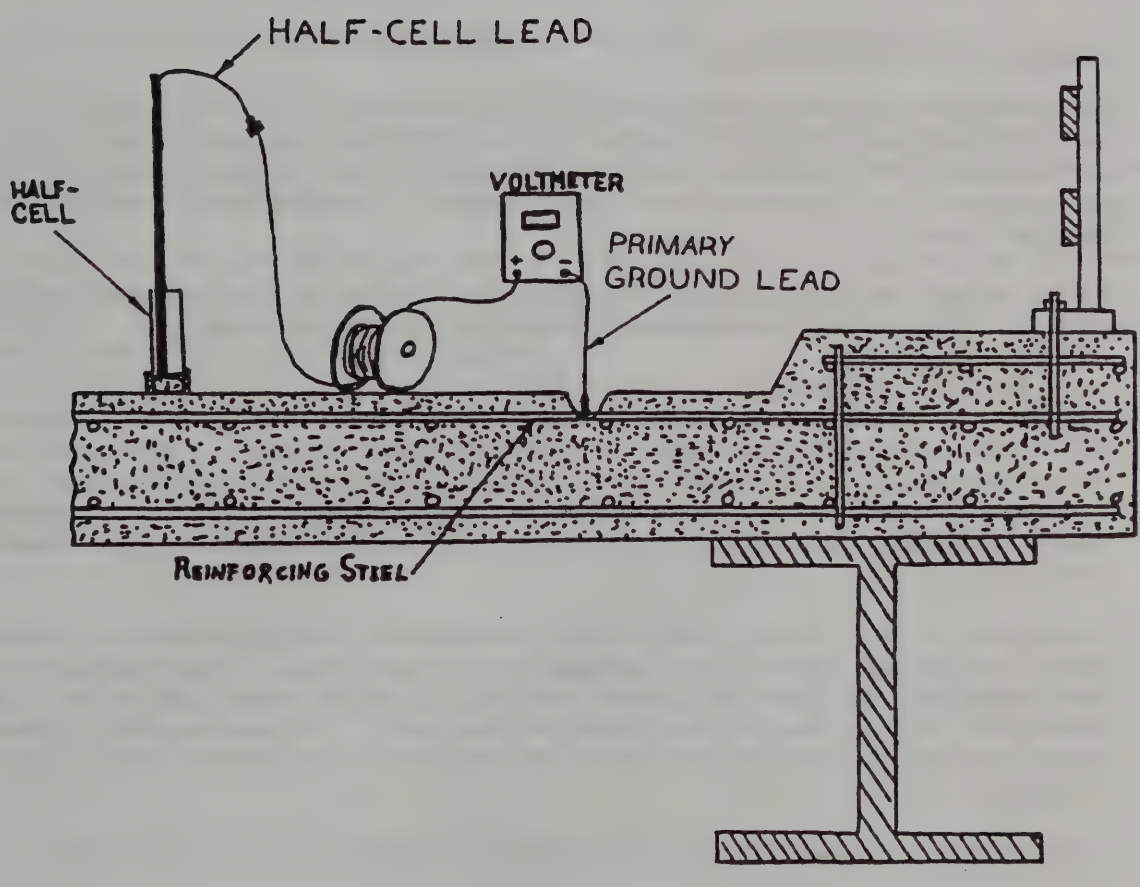

Figure 3-3. Corrosion potential equipment.

E. Precision Check

1. Place porous end of half-cell covered with the wet sponge on one of the pre-wet grid points and observe meter display. If reading is stable, i.e. does not change by more than 0.01 volts after 15 seconds, make a note of the observed voltage.

2. Disconnect half-cell, re-connect it and repeat the measurement at same point on the deck. If readings vary by more than 0.01 volts, equipment is not functioning properly and should be checked.

3. When equipment is not functioning properly, replace the first half-cell with another half-cell and repeat the measurement at same grid point. Readings should not vary by more than 0.02 volts. Failure to satisfy these requirements may indicate a faulty half-cell, e.g. unsaturated copper sulfate solution, or a defective ground to the reinforcing steel. When any problems have been corrected and satisfactory precision checks obtained, proceed with the corrosion potential survey.

F. Obtaining Potential Readings

1. Switch meter range to read 0.00 volts and zero meter, if necessary. Place the half-cell on first grid point. Potential reading should stabilize in a few seconds. If reading does not stabilize, the concrete may not be sufficiently wet and more electrical contact solution should be applied to the grid points.

2. The half-cell is moved along the deck and placed in firm contact with the concrete at each grid point until a stable reading is obtained.

3. The corrosion potential for each grid point should be recorded in the appropriate position on a bridge deck condition survey form (BR344, 10x10 grid paper, or some other suitable format) exactly as it appears in the meter display. In general, the readings should fall between 0.10 and 0.60 volts, however, it is possible on rare occasions to obtain negative readings at some locations. When this occurs, the negative sign should be entered.

4. Occasionally the survey crew should re-measure the potential of certain points to insure that their readings are reproducible. Readings made on the same point on the same day should not vary by more than 0.02 volts. These additional values are not recorded on the form. If readings vary, the crew should check their equipment and connections to determine the cause of variability.

5. Completed data forms should be processed as outlined in Chapter VIII.

G. Precautions

1. Decks that have free standing water due to rainfall are not suitable for measuring corrosion potentials. Excess moisture conducts current from areas of high potential and the voltmeter will register the high potentials even when no corrosion is present below the half-cell. Once the deck surface appears dry, several additional hours of drying are required before potential readings will be repeatable.

2. Do not attempt to take readings through paint, asphalt or epoxy patches, or directly on an exposed reinforcing bar. Variation in the electrical resistance of the bar environment will cause the readings to be unreliable. If a suitable reading cannot be made within one foot of the actual grid point, leave the corresponding space on the survey form blank.

3. A separate ground connection must be made for each slab-span.

4. Corrosion potential measurements should not be made at temperatures below 4°C (40°F) due to the possibility of moisture freezing in the deck. The difference between the electrical resistance of water and ice in the concrete will change the potential reading.

5. Electrical duct work in the deck or hanging from the underside, or overhead lines have been known to affect potential readings. Having the power turned off may be the only way to obtain accurate readings. If necessary, coordinate with utility companies.

IV DELAMINATION DETECTION AND SPALL LOCATION

Pressure exerted by corrosion products of reinforcing bars causes surrounding concrete to crack. In some cases, these cracks are horizontal and extend between adjacent bars in the top mat causing a delamination of the concrete above the bars from the rest of the slab. The action of traffic on the deck causes delaminated concrete to disintegrate, forming a visible spall on the deck surface. However, at any given time, numerous delaminations may exist which are not visible. These may be located by using a chain drag or a hammer.

Use of a chain drag to locate delaminations is based on the fact that sound produced by dragging chains over the deck surface becomes deeper or fuller as they pass over a hollow area. Experience has shown that this method of locating delaminations can be very accurate. In some instances, delaminations may fall between grid points used for corrosion potential measurements and may not be found by the potential survey. In this case, the chain drag or hammer is the best method available for locating these hidden defects. It is, therefore, very important that the entire deck be thoroughly checked.

In addition to delaminations, surface spalling and cracking of the concrete should be recorded since it may not be possible to make cover meter and corrosion potential measurements in areas of severe surface spalling. Include areas which have been patched with bituminous concrete or epoxy mortar because these materials must be removed as part of the deck rehabilitation.

A. Procedure

1. The chain drag is swung from side to side such that the chain links strike the concrete surface producing a jingling sound. When the sound changes noticeably to a deeper or more resonant sound, the chains are over a delamination. Similar variations in sound are produced by a hammer.

2. The limits of each delamination should be marked on the deck surface.

3. Spalls, cracks, and any other deterioration are located by visual observation. This includes spalls which have been temporarily patched with bituminous concrete or permanently patched with an epoxy mortar.

B. Documentation

The following defects should be sketched on a copy of the 1"=10' drawing of each slab-span:

1. Cracks
2. Delaminations
3. Spalls
4. Bituminous concrete or epoxy mortar patches
5. Any other deterioration noted

During preparation of contract plans, these defects will be transferred to plan sheets or added to concrete removal maps. Since this drawing will be used to estimate quantities of repair work, it should be fairly accurate as to size and location of defects. The completed drawing is processed as outlined in Chapter VIII.

V DATA VERIFICATION-CALIBRATION CORES

Although methods described in Chapters III and IV are adequate to determine the kind and extent of concrete removal required, it is necessary to verify data accuracy and to resolve any apparent contradictions in results. This is accomplished by taking several partial depth cores at selected locations on the bridge deck.

A. Core Location

In general, shallow cover depth and high corrosion potentials are associated with delaminations, spalls, and cracks in concrete. However, when contradictory results occur at a particular location, the deck should be cored in that area to determine which, if any, of the data is incorrect. Examples of such contradictary data are:

(1) thick cover (3" or greater) and high potential reading (0.40 volts or greater)
(2) thin cover (1" or less) and low potential reading (0.15 volts or less)
(3) delamination and low potential reading (0.25 volts or less)
(4) adjacent grid points with a large difference in potential in a delaminated area (0.25 to 0.45 volts)

In addition to cores taken to resolve any discrepancies in data, calibration cores should be taken from each area representing a different class of concrete removal on each slab-span. The number of cores taken should be kept to a minimum. The intent of this procedure is to confirm survey data at representative locations. On multiple slab-span structures or multi-lane structures, the number of cores taken on each slab-span should be reduced accordingly to keep the coring effort manageable. Any color photographs of cores should be taken as soon as practical, preferably within twenty-four (24) hours after removal from the deck, as new rust deposits will form on any reinforcing steel.

B. Core Record

A core record similar to Figure 5-1 (Blank BR 193 included at end of Appendix) should be completed for each slab-span. The record should include core location, cover meter data (optional), actual depth of cover, corrosion potential, condition of steel, presence of delamination and cracks, and any pertinent remarks. Each core must be broken open at the top reinforcing bar level to examine the condition of the steel.

BR 193 (2/88)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

BRIDGE DECK CORE RECORD

RT# 9 (DUNN BRIDGE) | OVER HUDSON RIVER | DATE 2/22/88

BIN# 1093029 | REGION 1

COUNTY ALBANY-RENSSELAER | FILLED OUT BY JOHN JONES (PET)

CORE NO.	LOCATION		DEPTH OF COVER		DELAMINATION		CORROSION POTENTIAL	STEEL CORROSION	CRACKS	REMARKS
	LONG.	TRANS.	PACH.	ACTUAL	CHAIN DRAG	CORE EXAM.				
1	15	5	2¼"	2"	NO	NO	0.22	NONE	NONE	CLEAN STEEL
2	25	5	1"	1⅛"	YES	YES	0.38	MEDIUM	NONE	BAR PITTED ALL AROUND
3	45	10	1¼"	1¼"	NO	YES	0.33	LIGHT	NONE	PITS ON TOP OF BAR
4	45	20	1½"	1⅜"	YES	YES	0.43	HEAVY	NONE	LOOSE RUST
5	50	15	2"	1⅞"	NO	NO	0.41	MEDIUM-HEAVY	YES	CRACK AT BAR
6	75	20	1¾"	1½"	NO	NO	0.39	LIGHT-MEDIUM	NONE	ADJACENT TO SPALLED AREA

Figure 5-1. Core record.

C. Interpretation of Results

Corrosion potential readings generally indicate the following conditions.

Corrosion Potential (volts)	Condition of Steel Reinforcement
Less than 0.20	No corrosion
0.20 to 0.34	Light to moderate corrosion
0.35 to 0.50	Moderate to heavy corrosion
0.51 to 0.75	Heavy corrosion
GREATER THAN 0.75	BAD GROUND

Most cores should agree with these guidelines if the potential data is correct, however, some individual cores may not. It is possible to obtain a corrosion activity reading at some distance from its location, and it is also possible that a previously rusted area may have stopped corroding and may exhibit a low potential. If most cores comply with the criteria shown above, the corrosion potentials may be assumed to be correct. Similarly, most cores should agree with any cover meter results for depth of cover.

The completed core record should be processed as outlined in Chapter VIII.

REINFORCING BAR CORROSION

The steel bar in the right core would have an expected potential of 0.20 volts or less. The one on the left would have an expected potential of 0.35 volts or more. When removed, the steel in the left core contained black rust areas which soon turned orange due to exposure to oxygen.

VI DEPTH OF CONCRETE COVER OVER REINFORCING STEEL (optional)

The time required for deicing salts to penetrate to the reinforcing steel level is related to concrete quality and depth of cover. Therefore, the final grade of any repair work must be designed to provide sufficient concrete cover. Depth of cover can be determined by a cover meter, an instrument which measures the change in its magnetic field due to the proximity of a steel object.

A. Determination of Depth of Cover

1. Cover meter readings are taken at the same transverse spacing, but at twice the longitudinal spacing (ten foot intervals) as corrosion potential measurements.

2. At each grid point, locate the longitudinal reinforcing bars and mark their location.

3. Place the probe between the longitudinal steel and parallel to the transverse steel. Move the probe sideways until the lowest depth of cover reading is obtained. The probe is now directly over a transverse bar.

4. Read the meter scale for appropriate bar size and determine depth of cover to the nearest 1/4 inch. The depth is recorded as a decimal number on the bridge deck condition survey form.

5. Areas adjacent to spalled areas which contain exposed rebars are good areas to check meter accuracy. The exposed bar depth can be measured with a ruler and should be very close to the cover meter reading taken on the same bar in the area adjacent to the spall.

6. Completed data forms should be processed as outlined in Chapter VIII.

B. Precautions

1. Any ferrous metal objects in close proximity to the probe will affect readings. Readings adjacent to grates, metal joints, etc. will probably be incorrect.

2. Aggregates such as iron ore tailings may affect accuracy.

3. Occasionally check the cover meter zero set.

4. Transverse reinforcing bars in skewed bridges may be on a skew or perpendicular to the centerline. Orient the probe accordingly (parallel to transverse bars) when testing.

5. Measurements should not be taken at temperatures below 4°C (40°F) because the cover meter is not sufficiently sensitive at those temperatures to give accurate readings.

6. Electrical lines, ducts, etc. will affect readings.

7. When thick cover is present, a full depth core should be taken to check position of reinforcing steel mats. There have been decks where the top mat rested on the bottom mat.

VII CHLORIDE ANALYSIS (optional)

The quantity of chloride ions present in concrete at the reinforcing steel depth is one factor affecting corrosion. Quantity is related to structure age, amount of deicing salts applied, and concrete permeability. Since these parameters are fairly constant for any one structure, it is not necessary to take as many chloride samples as compared to corrosion potential or depth of cover measurements. And, since concrete cover must be removed in areas of spalling and delamination anyway, chloride samples are only taken from apparently sound areas. Chloride content analysis is performed on powdered concrete samples.

A. Location And Number Of Samples

Chloride samples are taken along a single transverse line at points approximately one foot from each curbline and in one wheelpath in each twelve foot wide traffic lane. Figure 7-1 shows examples for two, three, and four lane structures.

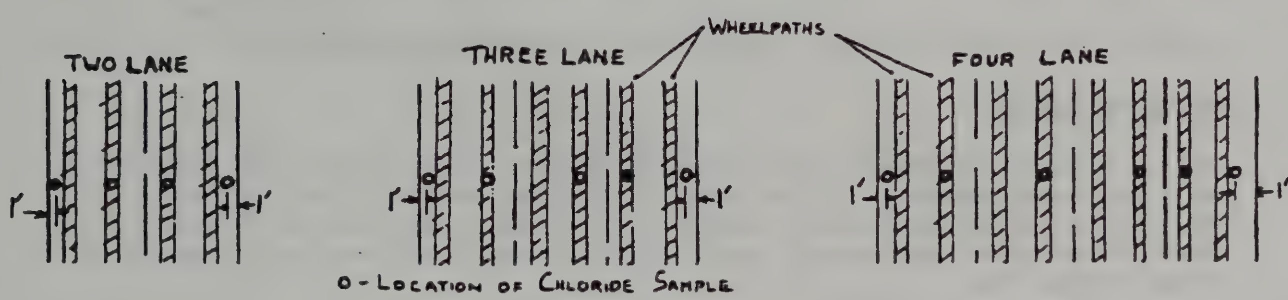

Figure 7-1. Location of chloride samples.

On single slab-span bridges, a single transverse line of samples should be taken in an area free from spalls, delaminations or excessive deterioration. If the entire deck is deteriorated, samples should be taken in the slab-span area in the best condition.

On bridges with multiple slab-spans, a transverse line of samples should be taken approximately every two slab-spans. For example, on a bridge with five slab-spans, a transverse line of samples should be taken on two of the slab-spans; on a deck with eight slab-spans, four slab-spans should be sampled.

The samples consist of powdered concrete removed from a drill hole at depths of 3/4 to 1-1/4 inches (nominal 1 inch), 1-3/4 to 2-1/4 inches (nominal 2 inch), and 2-3/4 to 3-1/4 inches (nominal 3 inch).

B. Sample Procedure

1. Select locations. Use cover meter to locate reinforcing steel. Care must be taken in locating the exact site of each hole to avoid striking the top reinforcing steel with the drill.

2. Set depth gage on hammer drill to 3/4" and drill to this depth with 3/4" diameter drill bit.

3. Blow concrete powder out of hole with a rubber syringe or other air blower apparatus. Make sure hole and surrounding concrete is clean of all powder.

4. Clean any accumulated powder from drill bit with a clean dry cloth. Set depth gage to 1-1/4" and drill to this depth.

5. Remove accumulated powder from hole with a small bent spoon or similar tool and place it in a separate 12 X 75mm culture tube or other clean container. Do not touch powder with your hands. Label culture tube with location number and sample depth as stated in C. Recording Samples. If cap is not airtight, wrap masking tape around the cap and tube.

6. Set depth gage to 1-3/4" and drill to this depth. Clean hole and surrounding area of powder. Clean drill bit with a clean dry cloth.

7. Set depth gage to 2-1/4" and drill to this depth. Repeat step 5.

8. Repeat above procedure to retrieve sample from 2-3/4 - 3-1/4" depth.

9. Samples and chloride sample log should be processed as outlined in Chapter VII.

C. <u>Recording Samples</u>

1. Set up a chloride sample log as shown in Figure 7-2 to record the location of each chloride sample as it is taken. A blank space is left for chloride content following each depth entered in the log. If a sample is taken at a depth other than the nominal one, two, and three inch depths, it should be shown in the log.

2. As each sample is placed in a culture tube, the location number assigned by the survey crew and the nominal depth at which sample was taken should be written on the tube using a permanent ink marking pen. For example, the chloride sample taken at a nominal depth of 2 inches, at longitudinal location 30, transverse location 15 on the eastbound slab-span number 1 in Figure 7-2 would be labeled 3-2".

CHLORIDE SAMPLE LOG

BRIDGE: Route 99 over PCRR BIN: 999 999

DATE: 3/9/77 TAKEN BY: Ernie Pandu

TRAFFIC DIRECTION	SLAB-SPAN NO.	GRID LOCATION LONG.	TRANS.	LOCATION NO.	DEPTH/CHLORIDE CONTENT		
EB	1	30	1	1	1/	2/	3/
			5	2	1/	2/	3/
			15	3	1/	2/	3/
			25	4	1/	2/	3/
WB	2	45	1	5	1/	2/	3/
			10	6	1/	2/	3/
			22	7	1/	2/	3/
			25	8	1/	2/	3/

Figure 7-2. Chloride sample log.

VIII PROCESSING SURVEY DATA

Data and samples collected by the survey crew must be forwarded to the appropriate agency for analysis and generation of the appropriate maps. In order to simplify the transfer, all materials related to a single structure and its approach slabs should be combined in one package. In case of exceptionally large structures with numerous slab-spans, the material may be further broken down into groups of slab-spans to speed processing.

Materials to be included in the package sent to the appropriate agency are:

1. Corrosion potential data
2. Depth of concrete cover data (optional)
3. Powdered concrete chloride samples and chloride sample log (optional)
4. Delamination, spall, patch, and crack locations (1"=10' scale drawing of deck showing location and outlines of all defects)
5. Core record

APPENDIX - REINFORCING STEEL CORROSION

THEORY AND MEASUREMENT

The corrosion of reinforcing steel in bridge decks due to deicing salt intrusion has been identified as the major cause of bridge deck spalling and delamination. For this reason it was necessary to develop a non-destructive test to determine if the reinforcing steel in an existing bridge deck was corroding. The California Department of Transportation adopted the copper-copper sulfate half-cell corrosion potential measurement test for this purpose. This appendix describes the theory behind that measurement and field procedures for measurement of reinforcing steel corrosion potentials.

A. Corrosion Reaction

Corrosion of reinforcing steel in concrete is an electrochemical process, which means it involves a chemical reaction and a transfer of electrical energy. The surface of the reinforcing steel is made up of many individual sites or electrodes which have different electric potentials with respect to their environment due to variations in the alloy structure, stress, environment, etc. These sites are known as anodes or cathodes depending on their electric potential. When two of these are externally coupled by an electrolyte or conducting medium, the electrode with the higher potential will supply electrons to the corrosion reaction and is called the anode. The other electrode which receives electrons is called the cathode.

It is the difference in electric potential between these sites which promotes the corrosion reaction. Referring to Figure 1, the metallic iron (Fe) at the anode has been converted to an iron ion (Fe^{++}) with two positive charges or "oxidized", i.e. it has had electrons removed. The two electrons which the iron lost travel through the reinforcing steel to the cathode as an electric current under the influence of the potential difference. The ions travel in the electrolyte (water) such that positive ions (Fe^{++} or H^+ from the water) move to the cathode. At the cathode, electrons may unite with two hydrogen ions (H^+) from water to form hydrogen gas (H_2), or another reaction may produce hydroxide ions (OH^-). Both reactions increase the number of hydroxide ions in solution, and those ions which unite with iron ions (Fe^{++}) form rust ($Fe(OH)_2$).

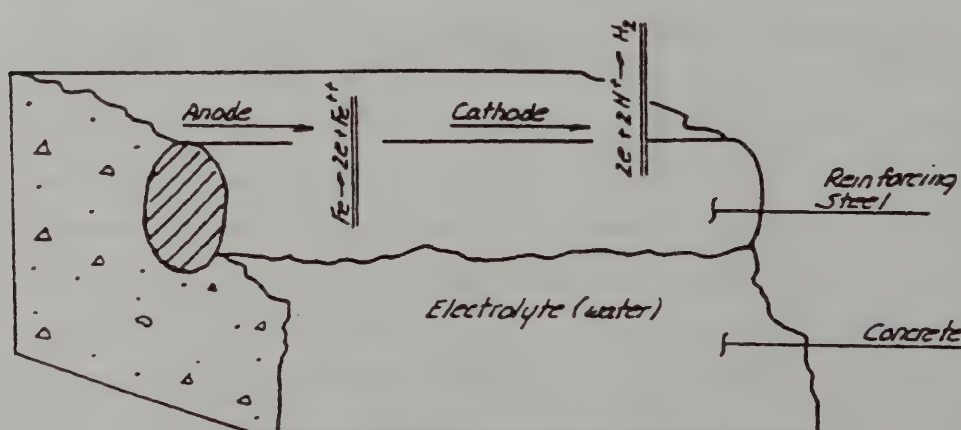

Figure 1. Corrosion reaction.

APPENDIX (continued)

The potential of a corroding electrode can be measured by using a reference electrode placed near the corroding electrode. As the reference electrode is moved toward one of the electrically coupled electrodes, it will interrupt current flow between the two and the potential gradient between them may be followed. At the anode where active corrosion is occurring, the higher electric potential will be found.

Under normal conditions, reinforcing steel in concrete corrodes at a very slow rate due to a characteristic of the steel known as "passivity". Due to the high pH of concrete (approximately 12), the oxidation reaction of steel at the anode is affected. When first exposed to wet concrete, steel initially corrodes very rapidly until it reaches the "critical corrosion rate" where steel passivates, i.e. a thin oxide layer is formed which acts as a partial barrier to further corrosion. If the steel environment does not change, the passivated reinforcing steel will corrode at such a slow rate that it will not produce the voluminous product necessary to damage concrete within the design life of the structure.

When deicing salts enter concrete, they upset the chemical equilibrium between concrete and reinforcing steel. The chloride ions (Cl^-) improve electrical conductivity of the electrolyte and destroy passivity by complexing the iron ion at the anode surface to produce $FeCl_2$. The $FeCl_2$ then reacts in solution with water (H_2O) to produce the normally observed $Fe(OH)_2$ and $Fe(OH)_3$, i.e. rust. The ultimate effect of these changes in the chemical environment is a marked increase in the corrosion rate of steel and early deterioration of the structural deck.

B. Copper-copper Sulfate Half-cell

The electrical potential which exists between a metal and its ions in solution cannot be measured directly because potential is not an absolute quantity. Potential must be measured relative to something of known or assigned potential. Since most corrosion reactions encountered involve water or aqueous solutions where hydrogen is present, the potential of the standard hydrogen half-cell reaction ($2H + 2e = H_2$) is defined as zero.

Using this as a reference, the corrosion potential of a metal can be measured using equipment such as that shown in Figure 2. If the hydrogen half-cell is used as the reference cell, the voltmeter reading would be the corrosion potential of test specimen in the corrodent.

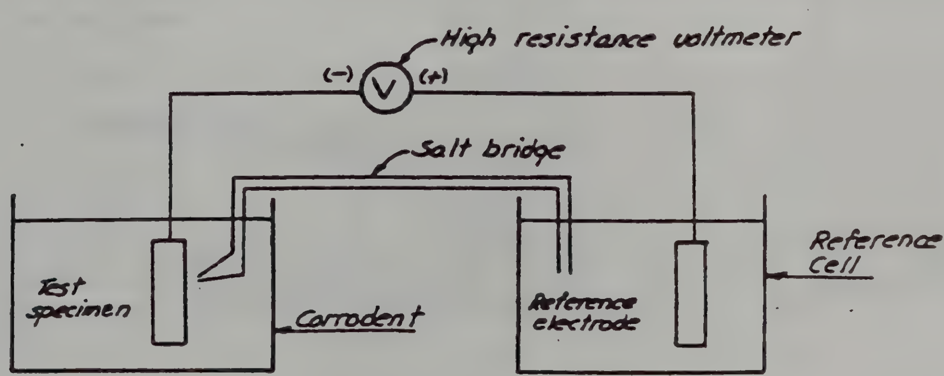

Figure 2. Equipment to measure corrosion potential.

APPENDIX (continued)

The hydrogen half-cell is not convenient for most measurements because the reaction involves a gas. However, any pure metal, which is in equilibrium with a saturated solution of its own metal ions, has a constant potential relative to the hydrogen half-cell. Since the potential of such a cell is not zero, the voltage measured in Figure 2 would not be the same. Rather than converting all readings back to the hydrogen reference, it is common practice to report the measured values relative to the reference cell being used.

Of many possible reference half-cells available, the most common one used for field work is the copper-copper sulfate half-cell. In this cell, a pure copper rod is suspended in a saturated copper sulfate solution (see Figure 3). As long as the solution remains saturated, no more copper ions can leave the surface of the rod without precipitating copper sulfate out of solution. Thus, the potential of the cell, i.e. the electric force opposing the solvation of additional copper ions, is a constant +0.3160 volts at 77°F (25°C) relative to the hydrogen half-cell.

It should be noted that there are two recognized and opposite conventions for the sign of the half-cell potential. However, the most widely accepted convention, and that used by the National Association of Corrosion Engineers, assigns positive values to more noble metals, such as gold and copper, and negative values to more active metals, such as iron and zinc, relative to the standard hydrogen half-cell potential. Following this convention, the corrosion potential of steel is normally found to be more negative than the copper-copper sulfate half-cell potential.

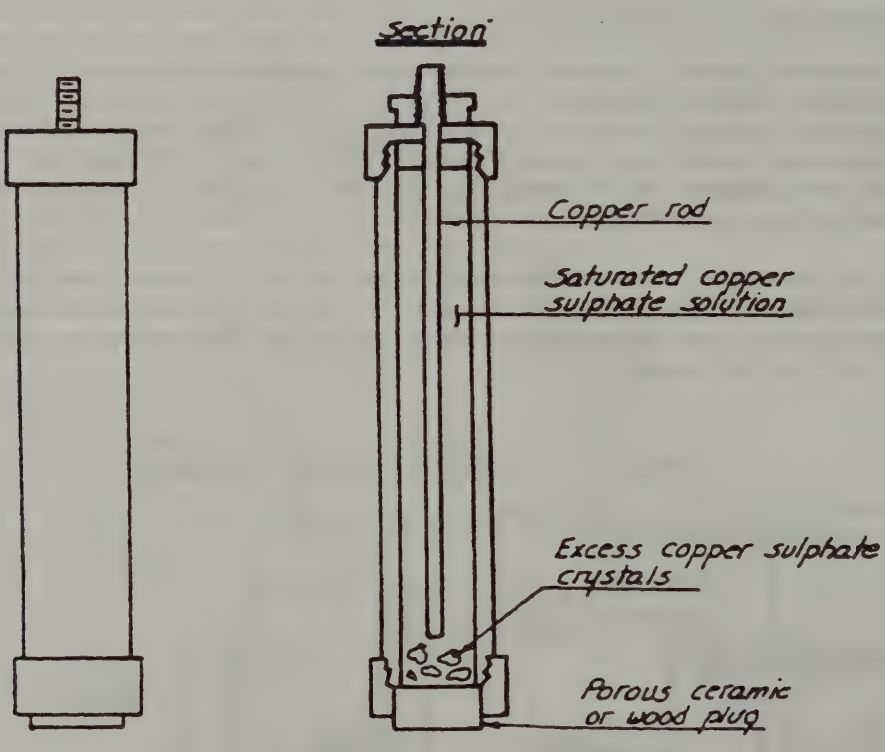

Figure 3. Typical copper-copper sulfate reference electrode.

The potential of the copper-copper sulfate half-cell varies with temperature, plus 0.0009 volts per degree Celsius increase (0.0005 volts per degree Fahrenheit). This variation is small enough that it can be ignored in the range of 19 to 31°C (67 to 87°F). Outside this range the reading must be increased for lower temperatures and decreased for higher temperatures. For example, if a measurement was made at 12°C, the voltmeter reading would be the algebraic difference between the half-cell potential and the corrosion potential.

$$(\text{Cu-CuSo}_4 \text{ Half-cell Potential})-(\text{Corrosion Potential})=\text{Voltmeter Reading.}$$

Since the half-cell is at 12°C, the half-cell potential is not +0.316 volts, but is lower by a factor of 0.0009 volts per degree. It can be seen from the equation above that the voltmeter reading must be corrected by the same factor. Assuming the reading was +0.362 volts, the corrected value would be found by the following equation:

$$\text{Voltmeter Reading} + (25^\circ\text{C} - \text{Half-cell Temperature})\ (0.0009\text{V}/^\circ\text{C}) = \text{Correct Reading.}$$

For the example given above

$$+0.362 + (25-12)\ (0.0009) = 0.362 + 0.0117 = +0.374 \text{ volts.}$$

In order to make the appropriate temperature correction to any field data, it is necessary to know the approximate average temperature of the half-cell during the period in which the measurements were made. For most purposes this can be assumed to be the average ambient air temperature at that location.

One other variable of the copper-copper sulfate half-cell is a phenomenon known as polarization. This occurs when a significant amount of current passes through the cell and causes a shift in potential. Obviously, a variation like this in the reference cell would certainly make potential measurements questionable. However, this shift is only significant when a substantial current on the order of 1 milliampere flows through the cell. If a voltmeter with a high internal resistance is used, only a few microamperes will flow in the circuit and there will be no significant polarization.

On the basis of work done by others, we can say with 90% statistical confidence that areas of reinforcing steel with a measured corrosion potential greater than 0.35 volts are actively corroding. Areas with a corrosion potential less than 0.20 volts are passive. Corrosion potentials from 0.20 to 0.35 volts represent an area of uncertainty.

As previously noted, the corrosion potential of reinforcing steel is usually more negative than the copper-copper sulfate half-cell potential. However, due to the arrangement of the half-cell and voltmeter, the value of the corrosion potential is read on the voltmeter as a positive number. The negative sign is implied in such readings although it is not reported. However, it is possible for the corrosion potential of the steel to be more positive than the copper-copper sulfate half-cell potential. In that case, the difference would appear on the voltmeter as a negative number and should be reported as such.

APPENDIX (continued)

C. Corrosion Potential Measurement Equipment

The typical equipment configuration used to measure reinforcing steel corrosion potential is shown in Figure 4. There are four major components: the voltmeter, copper-copper sulfate half-cell, ground connection to the reinforcing steel, and solution contact between half-cell and reinforcing steel.

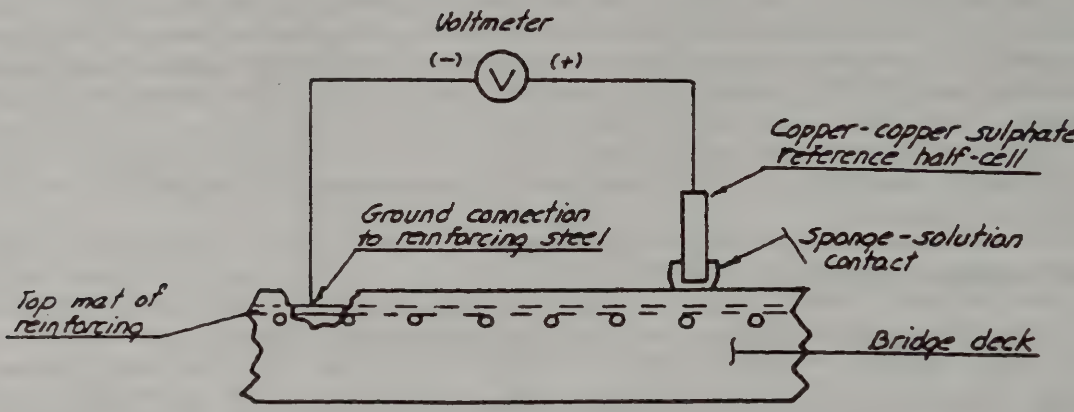

Figure 4. Equipment used to measure reinforcing steel potential.

Voltmeter. The voltmeter measures potential difference between the reference half-cell and reinforcing steel in vicinity of the half-cell. It is used with the negative or ground terminal connected to the reinforcing steel, and the positive terminal connected to the copper rod of the reference half-cell. To minimize current in the circuit, a high impedance voltmeter (100,000 ohms/volt or greater) should be used to prevent polarization of the reference half-cell.

Copper-copper Sulfate Half-cell. The half-cell provides a constant fixed potential reference necessary to measure corrosion potential of reinforcing steel.

Ground Connection to Reinforcing Steel. In order to measure corrosion potential of reinforcing steel, a good electrical contact (low resistance) between the negative side of the voltmeter and the top mat of reinforcing steel is necessary. Because of numerous contacts between reinforcing bars, a single electrical contact may be used for an entire slab-span of the bridge. Since reinforcing steel is not continuous over transverse joints, a separate ground must be established for each slab-span.

In the past, it was thought that any ground connection which provided a continuous electrical path to reinforcing steel was acceptable. Therefore, such various grounds as anchor bolts, bridge rail, armored joints and steel girders were used. However, use of these indirect grounds, based on their low electrical resistance, ignored another important electrical effect, coupling of dissimilar metals.

When two dissimilar metals are coupled in an electrolyte, they may create an electrical potential just as electrodes on the surface of reinforcing steel do. Unfortunately, if this additional potential is included in our measurement circuit, we no longer know what potential is being measured. For this reason, do not use ground connections which rely on contact through dissimilar metals such as galvanized bridge rail anchors or stainless steel anchor bolts. The only ground connection which can't introduce an additional unknown potential is a direct connection to reinforcing steel.

Solution Contact. In order to measure corrosion potential of reinforcing steel, a complete electrical circuit must exist. Trace the circuit in Figure 4 from the reinforcing steel through the voltmeter to the half-cell. At that point it is necessary to "connect" the copper sulfate solution in the half-cell to the reinforcing steel. The porous ceramic or wood plug in the half-cell is saturated with copper sulfate solution, but it may not be soft enough or large enough to make good contact with the bridge deck. For this reason, a sponge wet with electrical contact solution (see below) is wrapped around the tip of the half-cell to improve electrical contact and to reduce evaporation losses in the copper sulfate solution.

Concrete is not a good electrical conductor. Sometimes, an electrical contact solution must be used to wet concrete in order to complete the electrical circuit. Such a solution is composed of a mixture of wetting agent or liquid household detergent thoroughly mixed with tap water in the ratio of 1:200 by volume (3.2 ounces (95 milliliters) of detergent per 5 gallons (19 liters) of water). Under working temperatures less than 50°F (10°C), about 15% by volume (3 quarts or 2.8 liters) of either isopropyl or denatured alcohol must be added to prevent clouding. Clouding may inhibit penetration of the solution into the concrete.

The need for pre-wetting concrete with electrical contact solution can be determined by placing the half-cell on the concrete surface and observing the voltmeter to determine if the measured potential changes or fluctuates with time. A change greater than 0.01 volts in five minutes indicates that pre-wetting of the concrete surface is required. If the reading does not stabilize after pre-wetting, there may be excessive electrical resistance in the circuit which must be eliminated.

D. Field Procedures

Environment. In general, there are few environmental restrictions on measurement of corrosion potentials in bridge decks. As previously mentioned, temperature of the reference half-cell has only a minor effect. Therefore, the only temperature limitation is 0°C (32°F), where water contact between half-cell and reinforcing steel becomes inoperative. However, due to the time lag between ambient temperature changes and deck temperature changes, it is good practice to use 4°C (40°F) as the low temperature limit.

Potentials cannot be measured in the rain, on decks with standing water, or on excessively wet decks because the electrical path through water may extend a great distance from the half-cell location. For this reason, location and magnitude of corrosion potential is uncertain. It is good practice to wait several hours after a rain to allow any excess moisture to escape from the deck before measurements begin.

Equipment. Before any wiring connections are made, the voltmeter should be checked to insure its batteries are charged (refer to instruction manual supplied with meter).

Next, the copper-copper sulfate half-cell should be examined to see that it is filled with saturated copper sulfate solution. In order to insure that the solution remains saturated, excess copper sulfate crystals should always be maintained in the half-cell. Some half-cells have clear plastic sides where crystals are visible. If the half-cell has lost solution, it should be refilled with distilled or deionized water. Additional reagent grade copper sulfate crystals should then be added and the half-cell agitated until no more crystals dissolve. The half-cells are supplied with a rubber or plastic cap over the porous ceramic or wooden plug. This should be placed in position on the half-cell whenever it is not in use to minimize evaporation losses. A sponge wetted with electrical contact solution should be placed over the porous end of the half-cell when it is in use. Because the half-cell is temperature sensitive, it should be allowed to come to equilibrium with the ambient temperature before starting work.

Once voltmeter and half-cell have been checked, the first wiring connection is the ground to reinforcing steel. It should be made halfway along the slab-span to maximize the deck area which can be reached without relocating. The ground connection must be made directly to an exposed reinforcing bar. In some instances, "experimental" bridge decks already have electrical connections to the reinforcing bars and these should be used. If there are spalled areas where a reinforcing bar is sufficiently exposed to allow the placement of a clamp, the steel should be cleaned of all rust where the clamp will contact the bar.

The ohm scale of the voltmeter should be used to determine resistance of the ground connection by connecting the clamp lead to the negative (common) terminal of the meter and using a test lead from the positive side to contact the reinforcing bar adjacent to the clamp. The resistance should be less than 3 ohms. If not, the steel may need more cleaning or the clamp may need to be adjusted to make better contact. The ground connection should also be checked by measuring resistance between ground and other exposed reinforcing bars, anchor bolts, armored joints, etc. Although one or two points may not show a low resistance, the majority of these points should be below 5 ohms. If the reinforcing bar chosen does not yield a low resistance ground, it may be electrically insulated from the top mat and another bar should be used. A ground connection can only be used for measurements on a single slab-span, i.e. between successive transverse joints.

When ground has been established, sufficient wire should be reeled off the cable reel to reach from the ground location to the farthest point on the slab-span. If the wire isn't long enough to reach the entire slab-span, additional grounds will have to be established to complete it. The reel end of the cable is then attached to the positive terminal of the voltmeter. The voltmeter should then be set on a scale capable of reading the nearest hundreth of a volt. When using a digital voltmeter with three digits, this would be the ten volt scale. Finally, the other end of the reel wire is attached to the copper-copper sulfate half-cell.

Prior to taking measurements, precision of the equipment should be checked. First, a measurement should be taken at one location, the half-cell disconnected from the system, and reconnected. The measurement is now repeated at the same location. If the two readings vary by more than 0.01 volts, the equipment is not functioning properly and should be checked. The second check for precision is to measure the potential at one location using two different half-cells. If readings vary by more than 0.02 volts, the equipment is not functioning properly. Failure to satisfy either of these checks may indicate a faulty half-cell, i.e. contaminated, un-saturated copper sulfate solution, etc. It might also indicate a faulty meter, ground connection or circuit. Once the cause of the error is located and corrected, the precision checks are repeated. When satisfactory results are obtained, potential measurements may be taken.

It was noted previously that dry concrete is not a good electrical conductor. Therefore, pre-wetting with electrical contact solution may be necessary if stable readings can't be obtained. The concrete may be wetted by pouring a small amount of electrical contact solution on the surface at each measurement location. Another method is to place sponges soaked in solution at each location. The potential can then be measured by placing the half-cell on top of the sponge. Pre-wetting is satisfactory when the potential reading at a point is stable, i.e. it does not vary by more than 0.01 volts in five minutes. If stable readings cannot be obtained after pre-wetting, either the electrical resistance of the circuit is too great to obtain valid corrosion potentials, or stray current from a fluctuating direct current source, such as an arc welder, is affecting the readings. In either case, the problem must be corrected before measurements may be taken.

BR 193 (2/88)

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION

MATERIALS BUREAU

BRIDGE DECK CORE RECORD

RT# ____________ OVER ____________ DATE ____________

BIN# ____________ REGION ____________

COUNTY ____________ FILLED OUT BY ____________

CORE NO.	LOCATION		DEPTH OF COVER		DELAMINATION		CORROSION POTENTIAL	STEEL CORROSION	CRACKS	REMARKS
	LONG.	TRANS.	PACH.	ACTUAL	CHAIN DRAG	CORE EXAM.				